Symbology Development for Head-down Displays (SD-HDD) Proposed Experiment

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Outline of Presentation

- Summary of Preliminary Literature Review
- Goals and Objectives
- Research Performed to Date by SVS-GA Team
- Independent Variables (Candidate Symbology Concepts)
  - Terrain Portrayal Concepts
  - Guidance Symbology Concepts
- Proposed Scenarios
  - For Roanoke, Virginia – KROA
  - For Juneau, Alaska - PAJN
- Test Equipment and Assumptions
- Dependent variables
- Hypothesis
- Experiment Schedule

Motivation

- No terrain
  - NASA/FAA/AGATE sponsored experiments of HITS with mixed type of pilots but no Terrain Portrayal (TP)

- Terrain, Fixed Symbology
  - European research (Delft, Muenchen and Darmstadt):
  - Mostly proof of concept experiments, HUD, HMD, mostly professional pilots, focus on commercial and business type aircraft

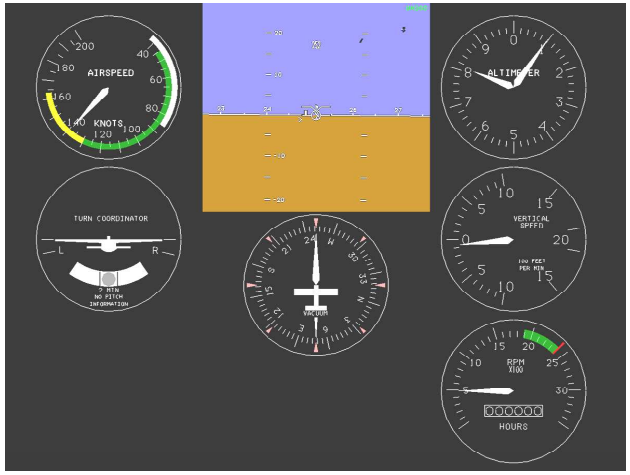
- Fixed Terrain, Fixed Symbology
  - Military experiments:
  - Most experiments with HITS, EVS, HMD, and HUD
  - Some experiments with HITS and TP in HDD
  - Highly trained military pilots

- NASA SVS-CAB experiments:
  - Focus of experiments on commercial and business type aircraft
  - Focus on CFIT not LVLOC

LVLOC Displays

Base Line AI —Size/Symbology→ EAI Display —Terrain→ SVS Display

- Airspeed, attitude, altitude, heading, and vertical speed indicators, turn/bank coordinator, and engine RPM



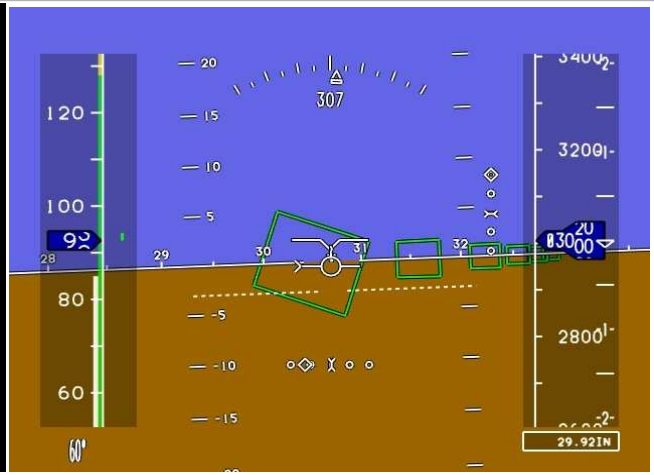
- Replace AI with horizon line, pitch grid, roll scale with sideslip wedge and a digital heading,
- Velocity vector with sideslip flag and acceleration caret.

- Fixed FOV=50
- DEM= 3 arc-sec
- Texturing, elevation based
- Otherwise same as EAI

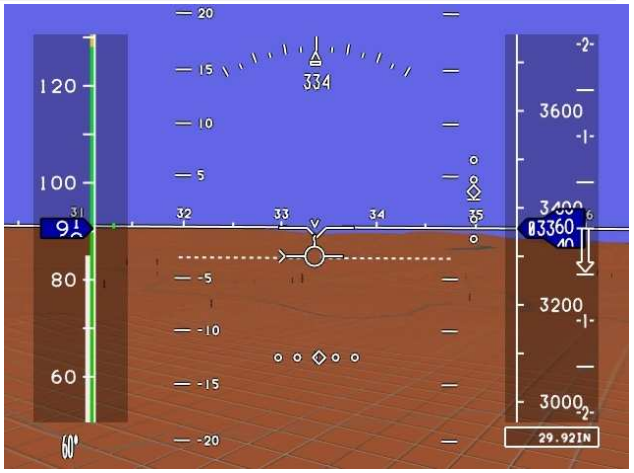
TP-HDD Displays

Baseline Round Dials → Blue Sky/ Brown Ground PFD → SVS PFD

- Airspeed, attitude, altitude, turn coordinator, directional gyro, and vertical speed indicator
- For approach scenario
  - Localizer/Glide slope deviation indicators
  - No tunnel



- Integrated Information on PFD
- Velocity vector with sideslip flag and acceleration caret
- Air data tapes
- FOV= unity, 30, 60, 90
- Horizon line, pitch grid, roll scale with sideslip wedge and a digital heading
- Tunnel for approach scenario



- Terrain Portrayed
- FOV= unity, 30, 60 and 90
- DEM= 1, 3 and 30 arc-sec
- Various texturing
- Otherwise same as BSBG
- Tunnel for approach scenario
- With and without tunnel on CCFN30 for approach scenario

Goals and Objectives of the Experiment

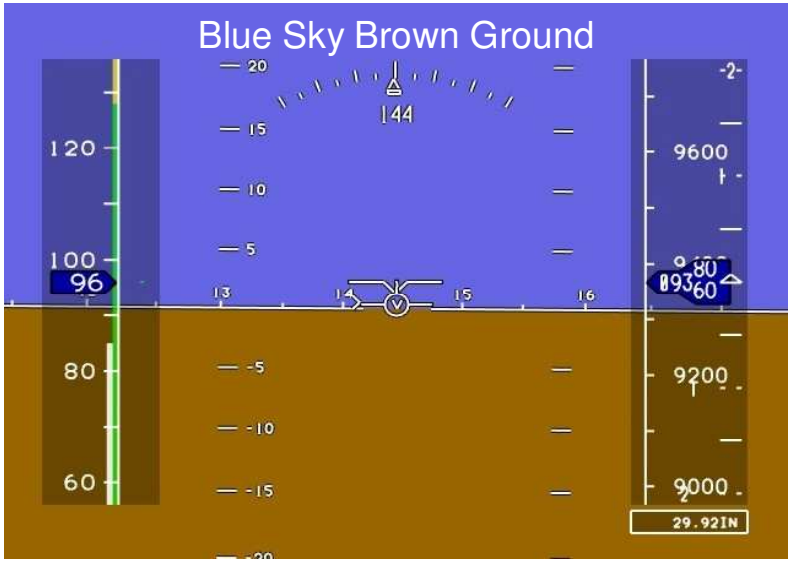
- Establish interaction between guidance symbology and terrain portrayal (TP) concepts on a Primary Flight Display (PFD) based on:
  - Pilot performance
  - Pilot workload
  - Pilot Situation Awareness (SA)
  - Rare event measures
- Develop recommendations for SVS-GA PFD symbology
- Demonstrate realistic operational concepts
  - Applicable to Small Aircraft Transportation Systems (SATS) operations

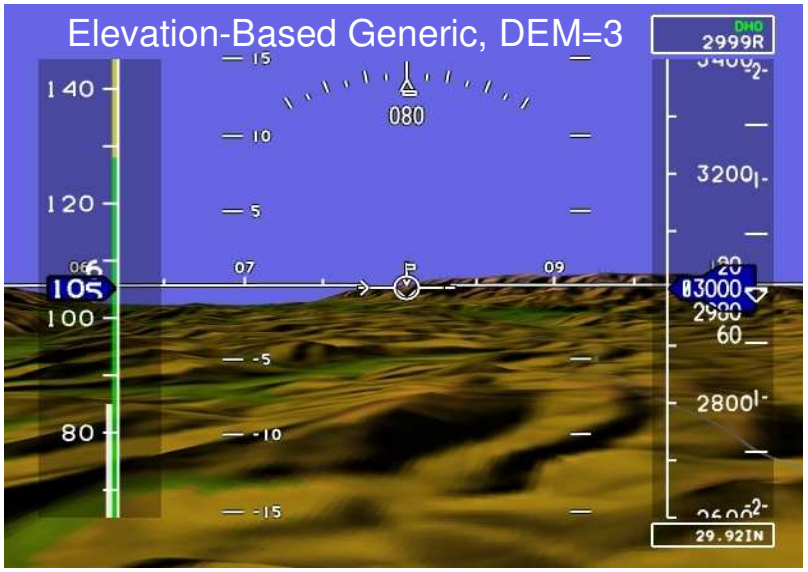
Proposed Independent Variables

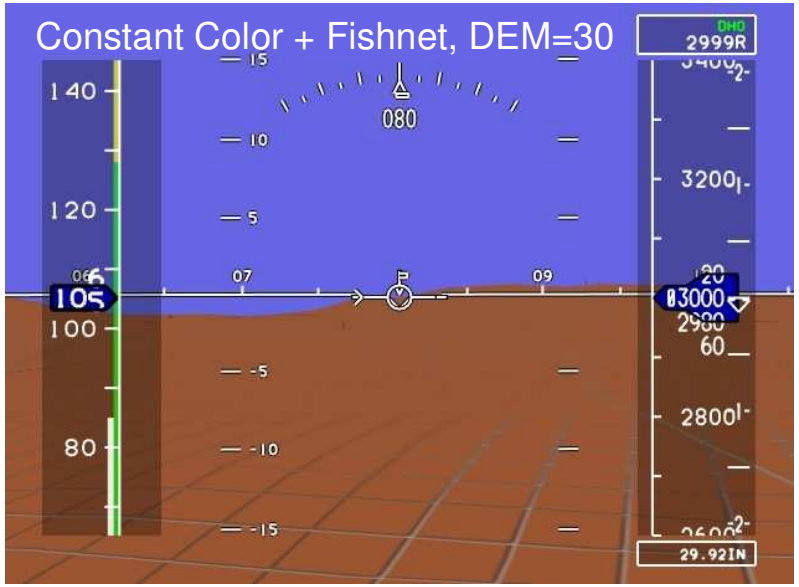
- **Following terrain portrayal concepts are being considered:**
  1. **Simple:** Baseline PFD, no terrain (BSBG)
  2. **Minimal TP:** 30 arc-sec DEM, Constant Color with Fish Net (CCFN30)
  3. **Medium TP:** 3 arc-sec DEM, Elevation based Generic (EBG3)
  4. **Complex TP:** 1 arc-sec DEM, Photo Realistic (PR1)

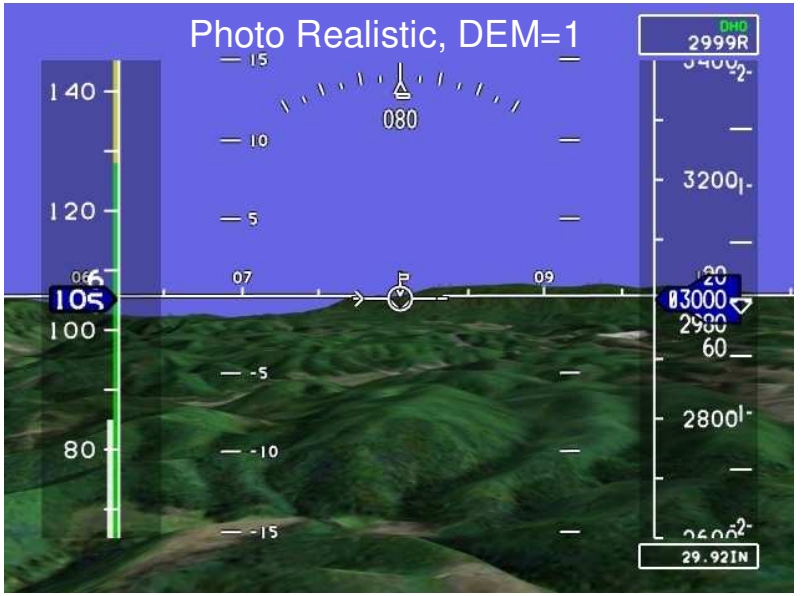
- **Following symbology concepts are being considered:**
  1. **Simple:** Raw data (CDI), no-tunnel
  2. **Minimal:** Raw data, add flight director, no-tunnel
  3. **Medium:** Unconnected box tunnel (Chelton) with guidance, TP-HDD
  4. **Complex:** Tunnel with follow-me airplane; NASA Crows-Feet Tunnel
  5. **Most Complex:** Rail-sliding box tunnel with gamma predictor; Rockwell Collins/TU Delft

Terrain Portrayal Concepts









Candidate Guidance Symbology Concept

1- Course Deviation Indicators Only

Candidate Guidance Symbology Concept

2- Pitch/Roll Flight Director

Flight Director: pitch Command

Flight Director: Roll Command

Candidate Guidance Symbology Concept

3- NASA TP-HDD w/ Chelton Tunnel

Candidate Guidance Symbology Concept

4- Crows-Feet Tunnel with Ghost Plane

Crows-Feet depict the 4 corners of tunnel cross-section

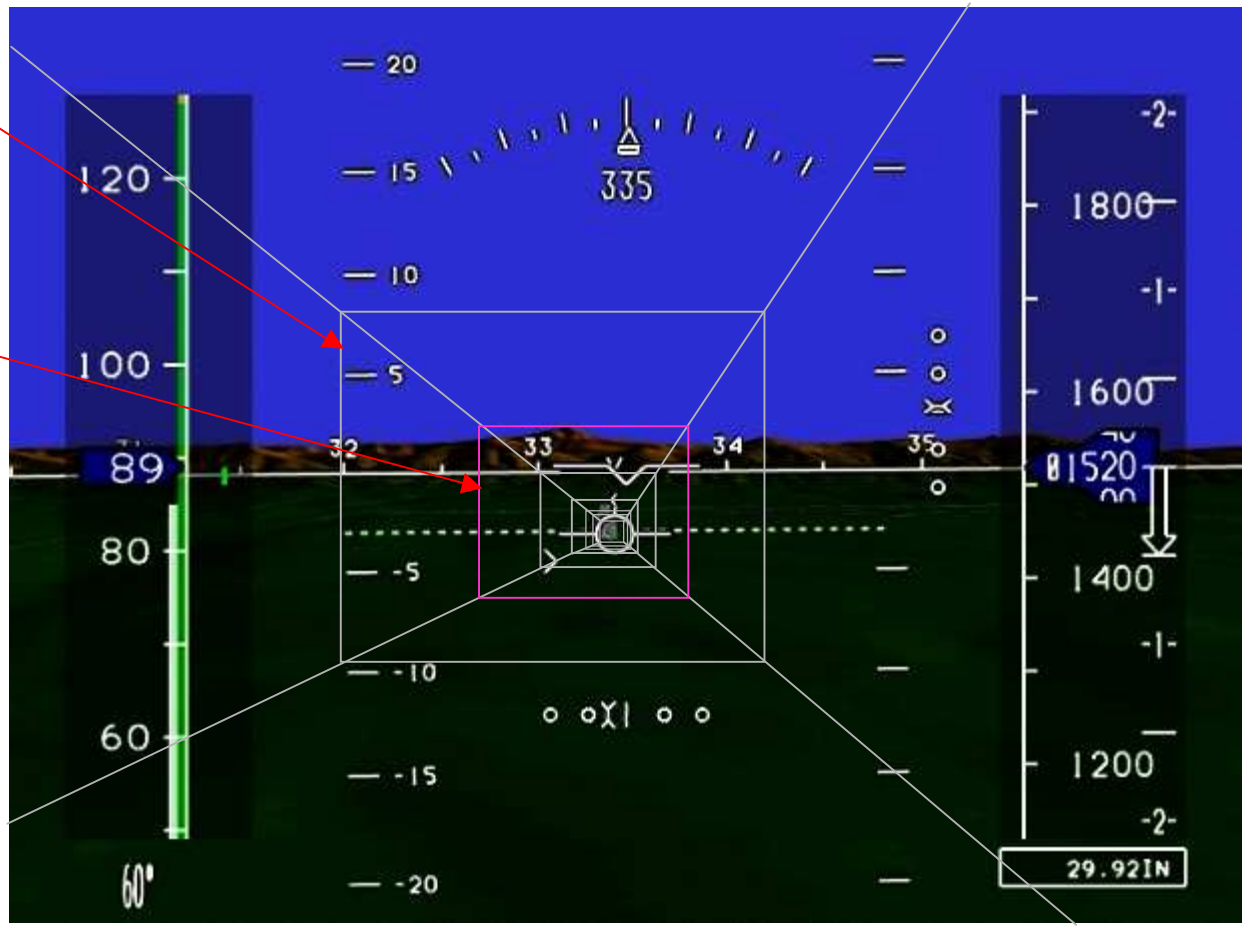
Ghost plane will be 5 seconds ahead

Candidate Guidance Symbology Concept

5- Rockwell Collins

Series of 300 ft by 300 ft squares connected by lines to form a pathway

Guidance box (magenta) is 5 seconds ahead



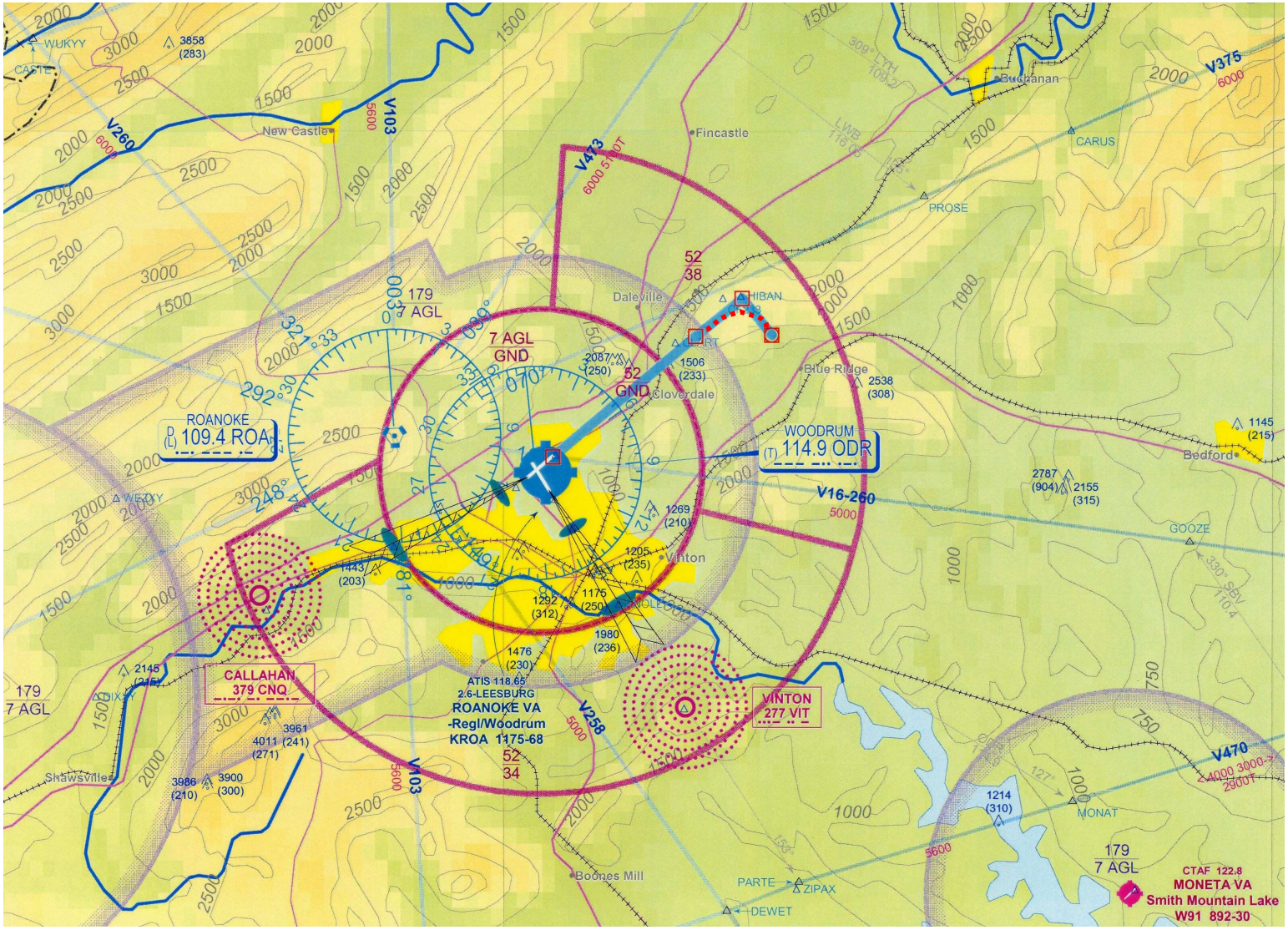
Proposed Scenarios

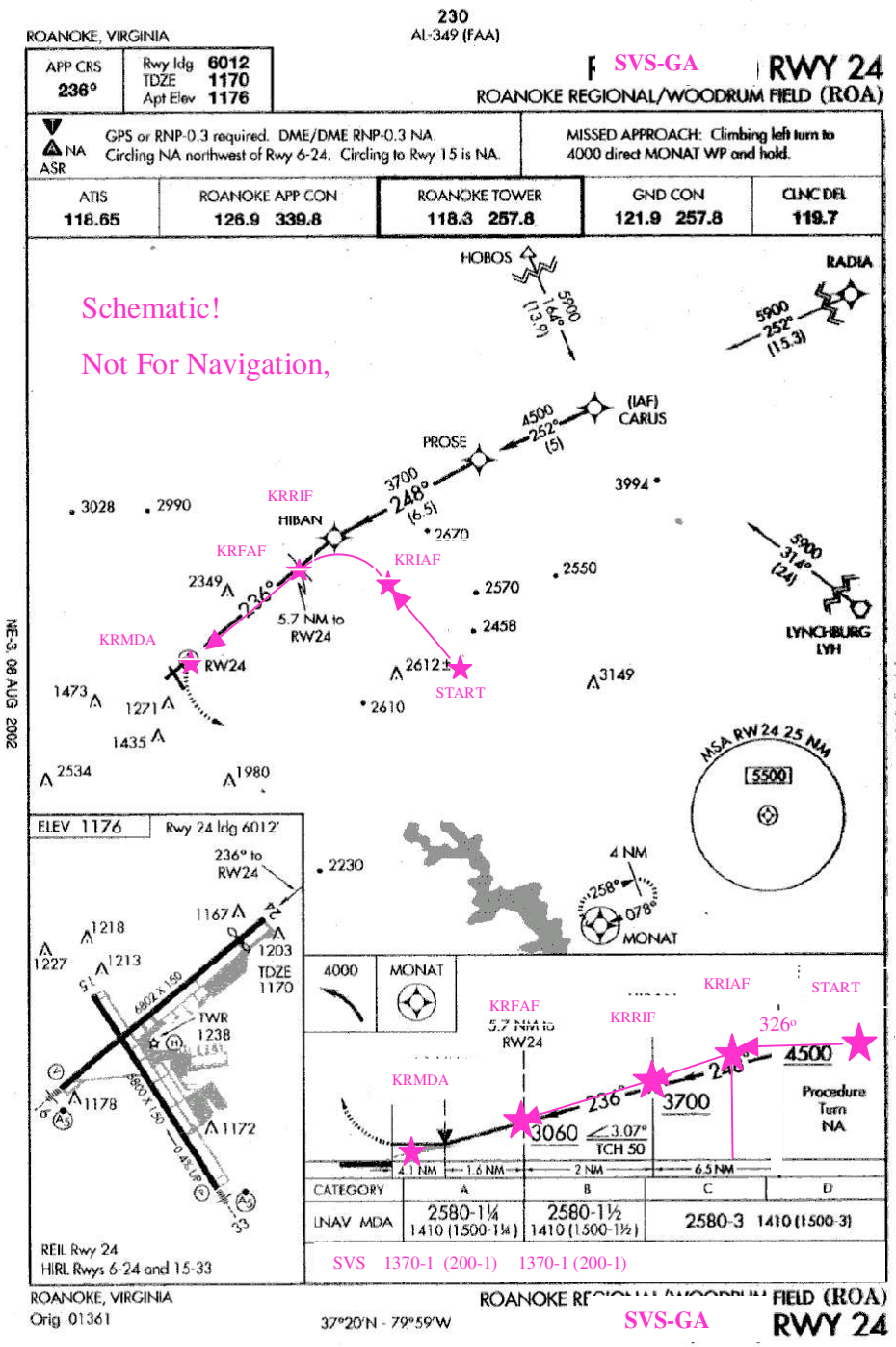
- Pilot Group 1 (KROA):

  - **SVS RWY 24 approach (10 minutes):**
    - Easy segment - Enter 1 NM before Initial Approach Fix (IAF)
    - Difficult segment - Descending 90^{o} turn at 6^{o} slope to fly a curve approach
    - Easy segment – Final Approach Fix (FAF) to Minimum Descent Altitude (MDA), 3^{o} slope

  - **Missed Approach RWY 24 and Hold (10 minutes)**

SVS Approach to RWY 24 KROA

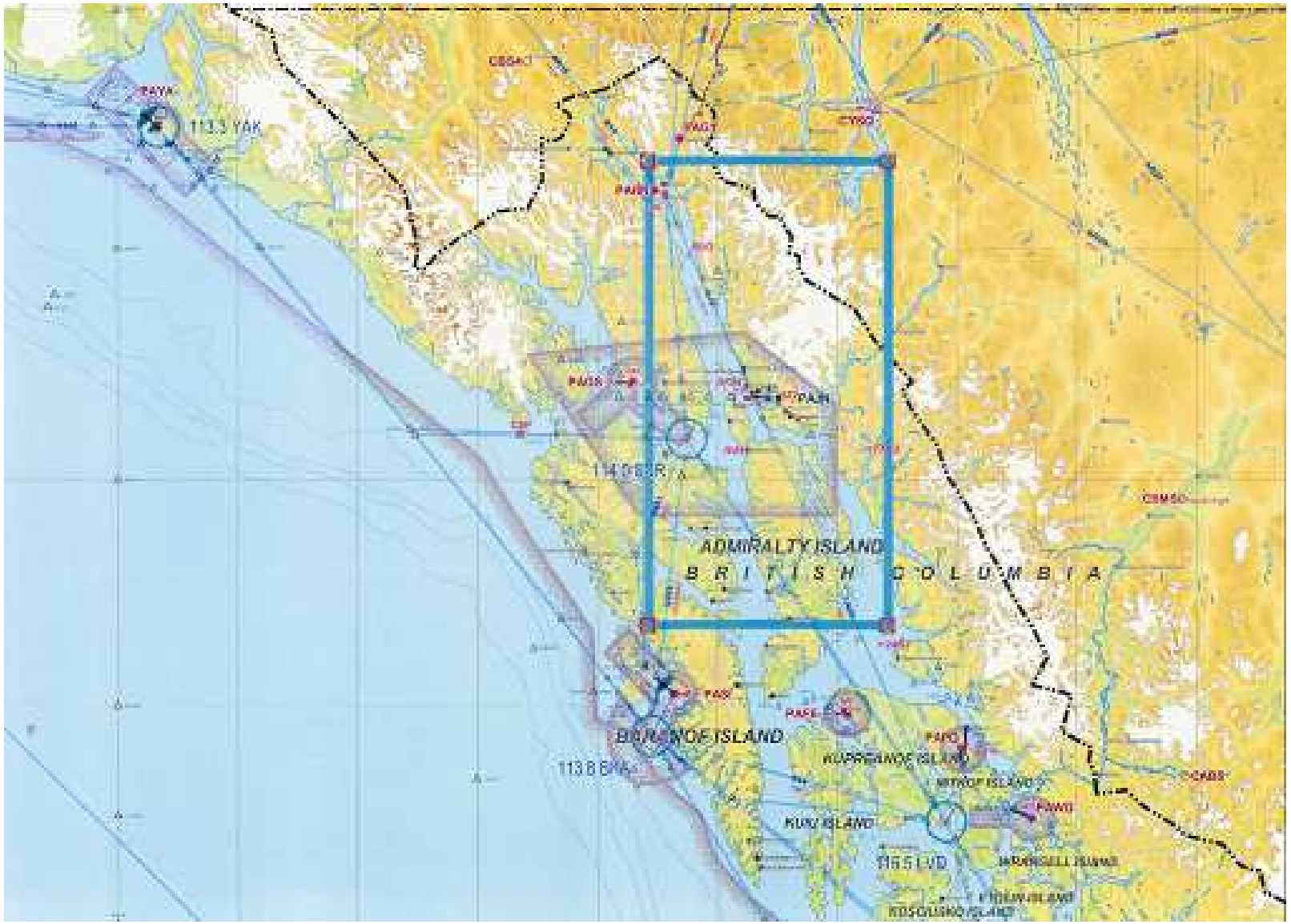



230
AL-349 (FAA)
ROANOKE, VIRGINIA
APP CRS 236°
Rwy ldg 6012
TDZE 1170
Apt Elev 1176
SVS-GA
RWY 24
ROANOKE REGIONAL/WOODRUM FIELD (ROA)
NA
ASR
GPS or RNP-0.3 required. DME/DME RNP-0.3 NA.
Circling NA northwest of Rwy 6-24. Circling to Rwy 15 is NA.
MISSED APPROACH: Climbing left turn to 4000 direct MONAT WP and hold.
ATIS 118.65
ROANOKE APP CON 126.9 339.8
ROANOKE TOWER 118.3 257.8
GND CON 121.9 257.8
CLNC DEL 119.7
Schematic!
Not For Navigation,
HOBOS
RADIA
PROSE
(IAF) CARUS
HIBAN
KRRIF
KRFAF
KRIAF
KRMDA
RW24
5.7 NM to RW24
START
LYNCHBURG LYH
MSA RW24 25 NM
5500
4 NM
MONAT
ELEV 1176
Rwy 24 ldg 6012'
236° to RW24
TDZE 1170
TWR 1238
REIL Rwy 24
HIRL Rwys 6-24 and 15-33
4000
MONAT
326°
4500
Procedure Turn NA
3700
3060
3.07°
TCH 50
4.1 NM
1.6 NM
2 NM
6.5 NM
CATEGORY
A
B
C
D
LNAV MDA
2580-1¼ 1410 (1500-1¼)
2580-1½ 1410 (1500-1½)
2580-3 1410 (1500-3)
SVS 1370-1 (200-1) 1370-1 (200-1)
ROANOKE, VIRGINIA
Orig 01361
37°20'N - 79°59'W
SVS-GA
RWY 24
NE-3 08 AUG 2002
NE-3 08 AUG 2002

Proposed Scenarios, continued

- Pilot Group 2 (PAJN):
  - **SVS RWY 8 Approach (10 minutes):**
    - Easy segment - Enter 1 NM before Initial Approach Fix (IAF)
    - Difficult segment - Descending 90^{o} turn at 6^{o} slope to fly a curve approach
    - Easy segment – Final Approach Fix (FAF) to Minimum Descent Altitude (MDA), 3^{o} slope
  - **Missed Approach RWY 8 and Hold (10 minutes)**

Proposed Scenarios, continued

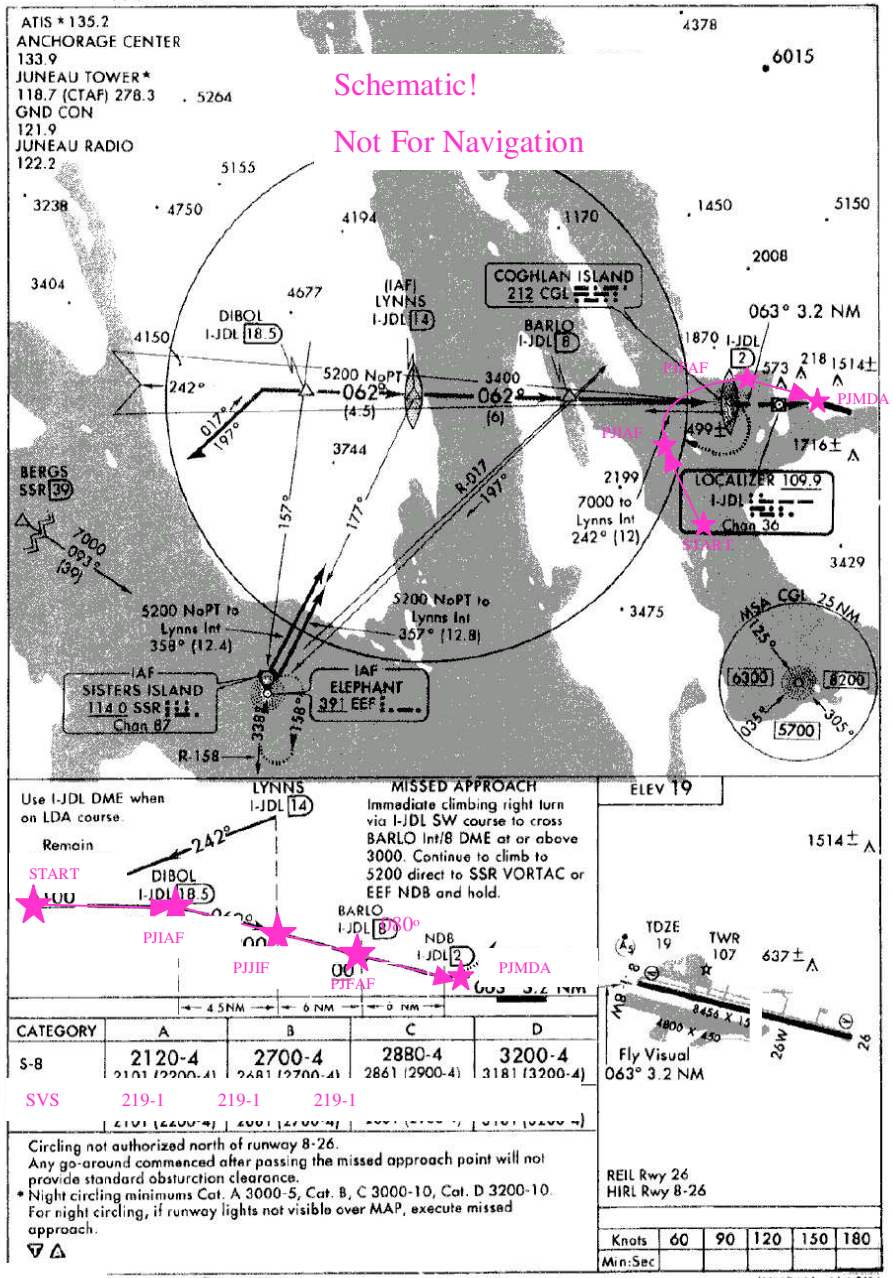


SVS-GA

RWY 8

AL-1191 (FAA)

JUNEAU INTL (JNU)
JUNEAU, ALASKA



Use I-JDL DME when on LDA course.

Remain

MISSED APPROACH
Immediate climbing right turn via I-JDL SW course to cross BARLO Int/8 DME at or above 3000. Continue to climb to 5200 direct to SSR VORTAC or EEF NDB and hold.

ELEV 19

CATEGORY	A	B	C	D
S-8	2120-4	2700-4	2880-4	3200-4
	2101 (2200-4)	2681 (2700-4)	2861 (2900-4)	3181 (3200-4)

SVS 219-1 219-1 219-1

Circling not authorized north of runway 8-26.
Any go-around commenced after passing the missed approach point will not provide standard obstruction clearance.
* Night circling minimums Cat. A 3000-5, Cat. B, C 3000-10, Cat. D 3200-10. For night circling, if runway lights not visible over MAP, execute missed approach.

REIL Rwy 26
HIRL Rwy 8-26

Knots	60	90	120	150	180
Min:Sec					

SVS-GA

RWY 8

58°21'N-134°35'W

JUNEAU, ALASKA
JUNEAU INTL(JNU)

Proposed Scenarios, continued

- **Possible Rare Event to invoke a CFIT**
  - Intentional Obstruction (tower/structure) in the path to simulate database error, out-the-window visibility below marginal VFR

- **Other possibilities**
  - Tunnel abnormality
    - Land short
    - Land long
    - Into terrain
  - OR other Abnormalities
    - Pitot static system errors
    - Engine out, emergency landing

Assumptions and Test Equipment

- **Similar to TP-HDD Set-up:**
  - A Cessna 172 will be simulated in GAWS
  - 8” VGA monitor (AVIDYNE?) as the HDD (PFD)
  - MX-20/GX50 as Navigation/Multifunction Display
  - FOV = unity, 30, 60, and 90
  - Out of window (NASA Research Terrain Databases)
  - Improved TP-HDD type aircraft state information

- **Follow-up flight experiment using NASA Langley Lancair**

Dependent Variables

- **Pilot/vehicle performance measures**
  - Pilot control inputs, path errors and aircraft performance data
  - Any special rare event measures
- **Pilot physiological measurements**
  - Skin Temp
  - Pulse rate
- **Qualitative pilot questionnaires**
  - NASA TLX, SART, SASWORD, CH
  - Audio/video recording of comments during the runs
  - Exit interviews

Hypotheses

- Adding terrain to PFD will improve pilot SA across all guidance symbology concepts
- Low fidelity TP concepts will favor complex guidance symbology, Rockwell Collins tunnel
- High fidelity TP concepts will favor simple guidance symbology, flight director or Chelton
- Pilot performance will be improved with tunnel concepts

Proposed Schedule

- Simulation Software Requirement Document (10/02)
- Simulation Hardware Requirement Document (10/02)
- Flight Software Requirement Document (11/02)
- Flight Hardware Requirement Document (11/02)
- Flight Critical Design Review (12/02)
- Simulation Software/Hardware Checkout (02/02-03/03)
- Simulation Experiment (04/03)
- Flight Test Software/Hardware Checkout (06/03)
- Flight Test Execution (8/03)

Pilots/Test Sessions

- **Total time for one evaluation pilot estimated to be 2 days :**
  - 4 TP x 5 SD = 20 displays
  - 20 display x 3 scenario = 60 RUNS
  - 60 runs x .2 hours = 12 hours
  - 12 + 4 hours questioners = 16 hours =2 working days

- **Evaluation pilot population will be a mix of pilots similar to TP-HDD experiment, total of 27+ ?**
  - 14 GA pilots, low time
  - 6 GA pilots, IFR-rated, low time
  - 4 specialists, high time
  - 3 Juneau operators, high time